The KidSat Project

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Abstract

Imagine viewing our world from Space; a world astronauts have described as "bright and vivid" with "no borders or boundaries". Then consider how much can be learned by studying Earth from this unique vantage point. The National Aeronautics and Space Administration (NASA) began a three-year pilot program in 1995 designed by a team of scientists, educators, engineers and high school and college students to share astronauts' unique view of Earth with middle school students. This pilot program was called KidSat. KidSat's primary objective was to merge real-time professional space flight with middle school education by providing students with equal access and direct contribution to the United States space program for the exploration of the Earth. KidSat's long-term intent was to produce higher student achievement and increased competence in science, math, technology and geography, and to promote an interactive understanding of Earth as an integrated system.

Similar to the regular duties of astronauts, scientists and engineers, students around the nation planned observations and captured images to study Earth's dynamic, fragile environment, using a remotely operated high-resolution color digital camera onboard the Space Shuttle, custom flight software, the Internet, NASA's infrastructure, and a mission operations infrastructure that linked middle schools to the Shuttle through a student-built Mission Control Gateway. Using accompanying curriculum, students determined which areas of Earth they wanted to explore and photograph along the Shuttle's flight path. Orbiting communications satellites and the Internet transmitted commands, telemetry and images to and from the classrooms. Via the Shuttle cargo bay video camera, NASA TV carried video of the mission for simultaneous viewing in classrooms.

The KidSat pilot program was conceived in November 1993 and ended in December 1997. This paper summarizes the results of this program.

Introduction

With the launch of Shuttle flight STS-76 in March 1996, NASA broke the age barriers to scientific exploration of our Earth from space (Way et al. 1995, Choi et al. 1995). For the first time, flight hardware configured and operated by young students was launched into space with the goal of collecting imagery to meet the exploration needs of middle-school students. Unlike many scientists who participate in Shuttle missions, these middle-school students did not wait until after landing to obtain and analyze their data. Instead they participated directly in the mission, modifying their image requests that were developed during the months preceding the mission, and capturing their data over the Internet in real time. As a measure of the quality of the scientific analysis that went on in the months following landing, a special session was held at the International Geoscience and Remote Sensing Symposium. Student representatives from each middle-school presented the best investigations from their classes. Two examples were speculation about the cause of a complete freezing of the Aral Sea in March 1996, and the controlling processes causing a change in the course of a feeder to the Amazon River over a decade.

Inspiration

The KidSat concept was inspired by a group of high school students working on a Shuttle mission as part of the Jet Propulsion Laboratory's (JPL) collaboration with The Johns Hopkins University Institute for Academic Advancement of Youth (IAAY) in a program called Challenge Awards. In this program, high school students developed the procedures and performed the training for Earth observations by the crews flying with the Shuttle Imaging Radar in 1994 (Way et al. 1994). The elements of the project that captured the interest of the students were the involvement in a real Shuttle mission, the astronauts' photographs of the Earth which provided a new perspective on the Earth and a transition to remote sensing, and the ability to explore unexplored territory. This program highlighted not only how valuable student involvement in a space mission could be for the students, but also how valuable students could be to the NASA mission and science teams. From these ideas, the KidSat Project was developed by JPL, IAAY and the University of California, San Diego (UCSD).

Goals of KidSat

The objectives of KidSat were to capture the interest of students through the human space program and to maintain this interest through Earth exploration; to advance the learning of middle school students through their participation in a NASA mission and through the use of the Earth images in the students' studies of science, math, technology, geography and other subject areas; and to develop an infrastructure that fosters student intellectual exploration and discovery using images of the Earth.

The technical objectives for KidSat were to acquire color digital images and color video of the Earth's surface, command the KidSat instrument from classrooms across the country using the Internet, provide the image data to classrooms across the country in real time during the mission using the Internet, provide tools that would allow students to do image analysis in their classrooms, and obtain data which could be used to design future KidSat instruments. There were several new technologies that made KidSat possible in the mid 1990's. These included the Internet, the Kodak digital still camera, the Shuttle's new communication system, and computers that could handle large image files and were cost-effective for schools.

The Pilot Program

NASA funded a three year research and development program to build the infrastructure and to develop and evaluate the curriculum needed for a larger operational program involving many schools. To make the program more appealing and exciting to young students, a partnership between the astronauts and the students was desired. The KidSat camera was therefore mounted on a piloted platform. There were three possible platforms: - the NASA Space Shuttle, the Russian MIR Space Station and, when built, the International Space Station (ISS). For the pilot program, the Shuttle was the best available option because it provided the appropriate command and data interface and was available for missions in the pilot years. However, the program looked forward to the time when the International Space Station would be available since it would provide continuous access to the KidSat instruments by an unlimited number of schools. The Mir station was also considered, however, limitations on data downlink prohibited the use of imaging systems on this platform.

In the first pilot year, 1995, the KidSat Team developed the instrumentation and infrastructure necessary to carry out the first mission. The project included the flight system on the Shuttle, a mission operations infrastructure, a data system, and underlying curriculum, teacher training and evaluation (Figure 1). In the second year of the pilot program, the first KidSat mission flew onboard Shuttle mission STS-76 on Atlantis. STS-76 was a mission to dock the Shuttle with the Russian Mir Space Station. It was the third such mission in a series of nine Mir rendezvous and dockings in Phase I of the International Space Station program. These missions were selected because the orbit inclination needed to rendezvous with Mir was 51° - an inclination that provided access to all of the United States except Alaska therefore providing opportunities for students in the United States to image their "own backyards". 326 pictures of the Earth were taken by the three participating middle schools. Improvements were made in the flight and data system as well as the school implementation, and schools were added on the second KidSat mission, which flew on STS-81 in 1997, another Shuttle/MIR docking. KidSat had 17 middle schools and 3000 students participating and 540 pictures were taken. Students became more involved in the analysis of the images. The third KidSat mission also came in the third pilot year onboard STS-86 which again was a Mir docking mission. Because of the success of the first two missions, this mission involved 52 middle schools and more than 6000 students, more advanced curriculum, upgraded flight, data and mission operation systems, and 656 pictures were taken (Table 1).

Web Site

The Internet was used by the KidSat Project both as an operational tool during the missions and as an interface to the data. The site remains on-line and is available for use by all (http://kidsat.jpl.nasa.gov/kidsat) The site consists of both project descriptions and direct access to the images.

Overall Infrastructure

The overall command and data flow between the ground and Atlantis utilized the Internet and an existing infrastructure of NASA satellites (Figure 2). From the classrooms, the Internet, orbit maps and atlases, along with students' interest, were used to develop commands which specified the times for photographing the earth. These commands were sent to the KidSat Mission Control Gateway at the University of California, San Diego where they were integrated with similar commands from other classrooms into a single Camera Control File (CCF). This CCF was checked and sent via the Internet to NASA's Mission Control Center (MCC) at the Johnson Space Center in Houston, Texas, where it was subsequently sent up to the Shuttle using the onboard communication (KCA/OCA) system via a link to the Shuttle that includes Domsat, White Sands, New Mexico, TDRSS and the Shuttle's Ku-band system. Once onboard, the CCF controlled the times photographs were taken. These photographs were then downloaded, usually during the night side of each 90 minute orbit, through the same TDRS/White Sands/Domsat system, to JSC. The images were then sent automatically to KidSat Data System at the Jet Propulsion Laboratory in Pasadena, California via the NASA Science Network (NSN). Once at JPL, the images were automatically processed and loaded into the KidSat Data System, and were online and available for the classrooms via the Internet only a few hours after capture and a few minutes after hitting the ground. The images were accessed in classrooms during the mission for validation and annotation, and were studied and developed into explorations post-mission. The student-enhanced images were stored and are available on the web so that students can share each other's discoveries via the Internet.

Flight System

The KidSat flight system was designed to enable remote sensing from the Space Shuttle for educational purposes (Lane et al. 1996, Baker et al. 1999) (Figure 3). The requirements for the flight system were that it acquire high resolution color photographs of the Earth similar to those obtained with hand-held cameras by the astronauts, that it be remotely operated using commands generated before and during the mission by students in middle school classrooms, and that it deliver the images in real time to the ground data system which then made the images available to the classrooms. The flight system included a digital still camera, a flight computer and its software, and the interfaces with the Shuttle. In addition, KidSat used one of the of four video cameras in the payload bay to acquire video of the earth, which was sent to the classrooms via NASA TV.

The payload was developed using existing NASA Space Shuttle Program-provided flight hardware. Custom software and cabling were developed to support the payload which used a modified Kodak DCS-460C camera for the digital camera, and an IBM ThinkPad for the flight computer. The Kodak camera had flown in a hand-held configuration on the Shuttle as the Electronic Still Camera (ESC) on previous Shuttle flights for use by the astronauts for in-cabin and hand-held Earth photography. For KidSat, the camera was bracket-mounted in the Shuttle's starboard overhead window. Bracket mounting provided a known pointing direction for the camera and eliminated the need for unnecessary crew interaction. This combination of flight hardware was ideal for the pilot flights because it involved minimal development and testing, available hardware, and routine integration.

The KidSat payload was developed by the Flight Team and was made up of students from La Canada High School, undergraduates from a variety of universities including Stanford University, the University of California, the California Institute of Technology, and Harvey Mudd, and engineers from JPL and JSC. The team had the responsibility of designating and obtaining the appropriate flight hardware, developing and testing the flight software, integrating and testing the hardware and software with the Shuttle (Figure 4), performing astronaut training, monitoring the operation of the flight system during the mission and handling any malfunctions, assessing flight system performance post-flight and making the necessary improvements for the next flight.

Mission Operations

One of the keys to the success of the KidSat project was the development of a mission operations scheme that could be scaled to allow many classrooms around the country to actively participate in the program. The mission operations component of KidSat was one of the elements that gave the students ownership, and made them participants instead of observers. The mission operations structure was designed to be interactive and dynamic, and consisted of: Student Mission Operations Centers (SMOCs) in the middle schools, where the initial planning took place both before and during the missions; links from the schools to a KidSat Mission Control Gateway (MCG) at UCSD, where these observation plans were verified and coordinated; and links from the Gateway to the Mission Control Center (MCC) at JSC, where the students' instructions could be sent to the camera in orbit and students in the Gateway could access the latest Shuttle orbit and timeline information.

Mission Control Gateway

The KidSat Mission Control Gateway functioned like a remote Payload Operations Control Center (POCC), connecting the investigators (in this case, the students in their classrooms) to their instrument, and was modeled after the new Shuttle/Space Station MCC at JSC. The MCG was housed in a building on the university campus and was set up with consoles, displays and computers similar to JSC's MCC. Internet and T1 connections to JSC and JPL provided the communication capabilities necessary to transfer command files, orbit parameters, mission information, voice and data. The Gateway was staffed around the clock during the missions.

In preparation for the flight, the Gateway developed a pre-flight timeline based on expected weather and lighting conditions, and the Shuttle's orbit. Simulations of the mission occurred during the weeks preceding the mission to refine procedures and give the students practice for the real mission. During the flight, the Gateway provided information to the SMOCs to monitor the Shuttle flight, the status of the KidSat instrument, and weather conditions around the world. This information was provided over the Internet in a format compatible with the computers at the SMOCs, and it gave the middle school students the ability to follow and participate in the flight, and to modify or update their scheduled observations.

The Mission Operations Team was made up primarily of undergraduate students from the University of California, San Diego. High School students from Tracy, and San Diego, California as well as high schools students from the KidSat Flight Team, also participated during the missions.

Student Mission Operation Centers (SMOCs)

Students in the SMOCs had the responsibility of determining where to take pictures and, once taken, to validate the information associated with their pictures (Rackley 1999). In the middle schools, small versions of JSC's MCC were set up such that students could perform key mission operations tasks during the KidSat missions (Nicholson and Block 1994). Using the Internet and web pages designed by the MCG specifically for KidSat operations, students were able to determine where they wanted to take pictures, determine the specific times to obtain these pictures, submit these times to the Gateway, monitor the validity of their commands and modify them if necessary, monitor the progress of the mission and whether their photos were successfully taken, download the photos from the KidSat Data System as soon as they arrived at JPL, and validate their location and associated information.

There were a variety of SMOC configurations. Some schools involved only one class in a SMOC and some involved classrooms from many schools in their district. Some SMOCs were set up in classrooms and some in dedicated areas in the schools or local facilities. Some SMOCs operated only during school hours, some included after school or even all night operations, as the Shuttle continued its mission and the KidSat camera continued it operations 24 hours a day.

The SMOCs used a variety of tools including computers, the Internet, atlases, clocks showing mission elapsed and local times, maps and books. A key tool was a slider map that showed the Earth and the current Shuttle orbit. The position of the orbit was specified by the equatorial node crossing; these node crossings were supplied by the Gateway as part of the SMOC web pages.

All positions in the SMOCs were staffed by students. The Missions Operations Director set the tone and pace for the SMOC. Every student performed a job which was critical to the operation of the SMOC and the success of the mission. Each SMOC had a slightly different set of positions but generally included a Flight Dynamics Officer (FIDO) who kept track of the Shuttle orbit, a Mission Targeting Specialist (MTS) who modified target requests based on the current orbit and added new sites based on current events or changes in student research objectives, an Environmental Specialist (ES) who kept track of weather and current events using the Internet, and a Public Affairs Officer (PAO) who interfaced with the outside world.

A Student's View of SMOC Activities (by Miranda Galindo)

Have you ever dreamed of working with people all around the world and with NASA ... taking pictures of the earth from two hundred miles above? Well for the students at KidSat this was no dream; it was a reality. KidSat students from Humboldt County worked with other KidSat students around the globe sending targets of their choice to the KidSat camera which was mounted on a Space Shuttle's overhead window. Once an image was taken of a target, it was sent back to the SMOC that sent the target through a complex satellite network. The final product was a picture perfect image of the target!

On the first mission, the Redwood SMOC successfully took forty seven images of the earth with the KidSat camera. The majority were amazing images of Amazon fires, Australian coastlines, coral reefs, Indonesian fires, South American cities, and many other locations.

The Redwood SMOC team, consisting of students from Pacific Union, Fortuna Elementary, Jacoby Creek, Cutten Elementary, Arcata High, and Fortuna High were trained at a 1997 Summer Academy run by local teachers. Students learned leadership skills and the importance of teamwork, orbital mechanics that are involved in a Shuttle mission, and the computer skills needed to do their job. Once the team was ready, their first mission began. On September 25, 1997, the Space Shuttle Atlantis launched from the Kennedy Space Center into orbit! Everyone was very excited about the launch, and a ceremony was held at Redwood SMOC. There was an atmosphere of anticipation as the count down began. "Three! Two! One!" Anxiety turned to relief as Space Shuttle Atlantis took off safely into space amid loud cheers.

The SMOCs were somewhat like the web of life. Each person depended on everyone else to do their job in order for the mission control room to be successful. Teamwork and communication with the rest of the team was essential. Each person performed their duty and constantly interacted with the rest of the team. Everyone was aware of what was going on at all times because of team communication.

KidSat was not just about acquiring images. There was a very extensive post-mission process. Images were researched for historical and geographic content and the images were annotated accordingly. Results were published in the form of papers and electronic reports. This work helped students understand our changing Earth.

After two missions, the Redwood SMOC and Pacific Union School hosted a Science Symposium. The Science Symposium was a chance for over one hundred students to have the opportunity to interact with experts who use spaceborne images of the earth and imaging processing software in their fields of expertise. These experts shared their knowledge through hands-on activities with the students.

A key element of the SMOC activities was to interact with the community and raise community awareness about students working on real life science and math projects in partnership with NASA and KidSat. Members of the team spoke to community organizations, created news releases, lead tours and talked with the press. Tours were provided to students, families, community members, state senators and Assembly members, as well as kindergarten students in astronaut suits and inquisitive college students. Local businesses provided support during the long hours of the mission. The SMOC's success at targeting images of the earth was shared with other schools throughout the world. It boggles yet satisfies the mind to know that students here in Humboldt County had these opportunities to lead the way for others.

The Data System

The KidSat Data System was responsible for acquiring, making accessible, and archiving the KidSat images once they reached the ground (Andres et al 1999). Additionally the Data System was responsible for providing the KidSat students with the image processing and scientific visualization tools to analyze the data once they reached the classroom computers. The overall design for the KidSat Data System was centered on the use of the Internet to link the students in the classrooms to the images. The Data System web pages allow students to find, view, verify and analyze the images. Three forms of search options are available. The Image Viewer (Figure 5) is web-based software that allows the KidSat user to view and download the image in various sizes, resolutions and data formats. The image viewer allows students to view the entire image at low resolution, or zoom in on any particular area of interest.

The Latest Image Search presents the images in reverse time order; the first image page includes the last images to arrive at the Data System. The images are presented in thumbnail format; by clicking on the image of interest, the Image Viewer is accessed. The Geographic Search option allows students to search any geographic area of interest by pointing and clicking on a map of the world. The last method for finding a particular image or set of images is the Form Search. Searches by geographical content (i.e., images with rivers) are based on the student validations.

Once students find an image they requested, there are several steps to be pursued in the analysis. The first step, image validation, was required for each image by the student or school who requested that image. Validation is the process to verify that the camera took the requested image and that the associated information was correct. The next two steps, annotation and exploration, can be carried out by any student or school for any of the KidSat images. Annotation, the second step, involves determining image content such as the names of the mountains, rivers, cities, and borders. These names are written directly on the images and submitted to the Data System for others to view. Exploration, the third and most exciting step in analyzing an image, went beyond naming the features in the image. This step encourages students to find out what the images expose about the Earth's history, science and geography. Explorations incorporate maps, weather data, books, the Internet, and other authorities.

In addition to analyzing a single image, combinations of images were used to provide a broader view of the earth. In some cases, several overlapping images were acquired. These series of images were mosaicked together to show a swath crossing a broad region revealing borders, terrain changes or coastal crossings (see Tseng et al 1999). In some cases, the overlap is sufficient for a stereo pair to be created. Students presented stereo pairs as anaglyphs or as left/right image pairs hat can be viewed with a stereopticon (Figure 6).

The Data System Team was centered in the Digital Image Animation Lab (DIAL) at JPL and was supported by the Solar System Visualization Team. The Data System Team's goal was to deliver the images to the schools in the most exciting ways technically possible. The team was made up of students from La Canada High School, La Canada Flintridge Prep, undergraduates from Harvey Mudd, USC, Cal Poly Pomona, and The University of Nebraska, and engineers from JPL's Cartographic Application Group, Multiple Image Processing Lab (MIPL) and DIAL. Weather data was obtained from the University of Wisconsin.

Education

The education of middle school students in fifth to eighth grade was the foremost aim of the KidSat project. This was achieved through the enhancement of middle school disciplines such as science, math, social studies, language arts and art. The Education Element of KidSat was designed by The Johns Hopkins University Institute for the Academic Advancement of Youth (IAAY). IAAY's primary responsibilities were to create a flexible and content rich curriculum for educators, conduct educator training workshops with follow-up support, provide a quantitative assessment of the value of KidSat in Middle School education, and provide mission support.

To meet these responsibilities, IAAY provided educators with supplementary curriculum that met individual student needs and that addressed district, state, and national standards (Geography for Life 1994, National Science Education Standards 1996); developed an infrastructure that fostered student intellectual exploration and discovery; designed teacher training and follow-up support; and provided continuous evaluation and improvement of the curriculum as needed. The Education Team was lead by JHU/IAAY and included a Core Curriculum Design Team made up primarily of teachers.

The Core Curriculum Design Team (CCDT), comprised of teachers, scientists, engineers and IAAY facilitators, was conceived to design the KidSat curriculum. The CCDT developed interdisciplinary lessons which integrated Earth science and technology with middle school subject areas. The team created three modules (Figure 7): an introductory module and two exploration modules (Stork et al. 1999). The CCDT was also responsible for the training of KidSat pilot teachers and contributed to project assessment through the evaluation of instructors and students.

The KidSat Summer Teacher Training Institute was held during two weeks in the summer preceding each mission for teachers implementing the KidSat curriculum. IAAY brought together pilot teachers with the CCDT, scientists, engineers, and school district curriculum specialists. Teachers were given the opportunity to work with the technology, annotate images, and participate in mission simulations. This hands-on experience enabled teachers to return to their classrooms excited and prepared to guide students through the KidSat experience.

The KidSat evaluation for the pilot implementation was aimed at measuring student learning. The evaluation encompassed two main forms of assessment: embedded assessment and standardized assessment. Embedded assessments are activities incorporated into the curriculum which have prescribed skill expectations to determine each student's understanding and progress.

The rationale for the embedded assessment was that it provided diagnostic information documenting student skill mastery, created a student portfolio, offered formative evaluation of student performance, provided avenues for individual student choices and accomplishments, provided feedback to gauge teaching effectiveness, and allowed for qualitative assessment of a hands-on curriculum. The second form of assessment was the Educational Record Bureau's (ERB) Comprehensive Testing Program (CTP) III. This nationally normed form of assessment was presented as a paper and pencil test requiring answers in a multiple choice format. The CTP III tested skills in writing, mathematics, and verbal and quantitative reasoning for both the KidSat students and a control group.

All data from the tests in the pilot phase were analyzed and reported for all participating KidSat students and the matched comparison group (Stork et al. 1999). Because most previously conducted studies on technology-based programs in the schools have focused almost exclusively on software evaluation, the results of the standardized testing provided interesting, if not insightful, information on the impact of KidSat on measurable ability and aptitude.

Exploration

Images from space can provide a much larger perspective of the world. Explorations incorporate KidSat images in investigating different aspects of the Earth. Explorations may focus on history, art, science, math, society, and other academic subjects. An exploration is documented like a scientific journal, the report scientists write on a discovery. Some of the explorations were posted on the Exploration Web page.

An Exploration Team, formed as part of the KidSat project, encouraged such exploration by creating examples in collaboration with scientists from NASA and universities. The KidSat Exploration Team was composed primarily of students from La Canada High School with participation from students of Arcadia High School and Leicester University. Below are two example explorations.

<u>The Aral Sea (by Students at Washington Accelerated Learning Center and from the KidSat Exploration Team)</u>

In the KidSat image of the Aral Sea (STS-76, image 00211835) we can see the eastern coastline and an island on the western side of the image (Figure 8). The westward movement of the eastern shoreline of the Aral Sea has uncovered the former sea bottom. The former sea bottom is the source of toxic dust. On windy days dust is picked up and blown across the farmland. The western shore has a much steeper embankment. Coastline changes are much less dramatic on the eastern shoreline.

The Aral Sea level has dropped 12-15 m. This drop, due to the diversion of water from feeder rivers, both the Syr Darya from the east, and the Amu Darja from the south, have been diverted. The rivers' water source lies in the mountain ranges west of the Himalayas, including the Hindu Kush, Pamirs, Tien Shan, Alayshiy Khrebet, and Kirghiz Khrebet. In the spring, snow melt from these mountains travels across an extensive arid region. The rivers are the only source of water to the Aral Sea. In the summer, demands for water from the rivers inhibits any water from reaching the Aral Sea. In the KidSat image, standing water in both delta regions indicate water may be flowing in the early spring. Kazakhstan and Uzbekistan, two countries that border the Aral Sea and four additional countries (Turkmenistan, Kyrgyzstan, Tajikistan and Afghanistan) use the water from the Syr Darya and Amu Darja rivers. The water rights are the subject of a new international treaty between these countries. Images from space may help document how well this treaty is being enforced.

One of the most striking features in the KidSat image of the Aral Sea is the extent of ice that covers the entire sea during the season when this image was captured in March 1996. Although the Aral Sea is usually partially covered by ice in the winter, it is unusual that it is completely covered by ice at this time of year. As the sea shrinks, the winters have become colder and harsher. The winter of 1996/7 was particularly cold and harsh.

Amazon River (by Jennifer Fox)

This image of a river in South America was selected by students in grades 5-8 at Buist Academy in Charleston, SC (Fox and Cowan 1996). The river is the Rio Xingu, a South American tributary to the great Amazon River in Brazil. There are scattered clouds over the river and the river's course can be distinctly seen as a muddy-colored waterway winding through the rain forest (Figure 9).

The Rio Xingu in northwestern Brazil is one of the 500 tributaries of the Amazon River. It flows from its source in the Brazilian highlands to a point to the north in the Amazon River Basin. The part of the Xingu that is shown in our image is winding and muddy brown. It is located just past the navigable portion of the river, which extends about 160 miles from the Xingu mouth. It was possible for us to locate the part of the river shown in the image by using the ONC maps because the image shows a distinct bend in the river and the image site was reported in exact longitude and latitude. After isolating the exact area of the image on the corresponding ONC map, the map's river was traced onto graph paper and enlarged to the size of the image. After the scales were synchronized, an outline of each river was made, and an overlay of these two pathways, seen in Figure 10, shows how the Xingu had changed over the space of a decade (the ONC map was made in 1987 and our project took place in 1996).

In addition to studying how the river had changed its course, the image provided us with a means to study one of the most valuable and endangered biomes on the earth: the tropical rain forest. Our image shows a small section of the largest river system in the world, an area important because of its rich soil and the irreplaceable environment it provides for floral and fauna life. Through the scattered cloud coverage on the image, distinct evidence of cleared rain forest can be seen. Once an area of the forest has been cleared for farming, the loss of plant life and root systems allows the important soil nutrients to be washed away by rain. With that land then worthless to the farmers, they burn down more valuable rain forest.

The Schools and the Students

Students were involved in two different roles in the KidSat Project. There were those in the middle schools who were the equivalent of a NASA science team, and there were those on the project who worked hand-in-hand with the scientists and engineers. The project students, primarily high school and undergraduate students, were responsible for building the project. They worked on designing and building the systems, writing the software, developing the web pages and operating the various systems during the missions. The middle school students were responsible for selecting the images and analyzing these images as part of their middle school curriculum.

At JPL, the majority of the students were from La Canada High School. They worked on KidSat as part of the Institutes for the 21st Century, a business and professional mentorship program. Some undergraduate students were involved through the Caltech Summer Undergraduate Research Fellowships (SURF) and Teaching and Interdisciplinary Education (TIDE) programs, and others were direct employees at JPL. At UCSD, the majority of the students were undergraduates with some assistance from graduate students, especially in the early development years. In addition, high school students participated in the missions as part of the State of California's School to Career Program.

Middle school students were chosen to be the "explorers" for the pilot program because the program could compliment many areas which the students were already studying - math, geography, history, computer science and Earth science. KidSat could fit into a teacher's curriculum without inhibiting other areas of study. The program in fact enhanced the other subject areas by associating them with an area of interest, space exploration, which encouraged students to want to learn. Initially, specific middle schools were selected on the basis of three criteria: urban schools, proximity to one of the institutional partners, and previous involvement with a Space Shuttle mission. Later in the program, schools associated with NASA centers across the country were brought into the program. The number of middle schools grew with each mission starting with just three for STS-76, and growing to 52 for STS-86.

Mission Highlights

The KidSat Flight System was set up by the crew about 18 hours after the launch of STS-76 following the first crew sleep period (Figure 11). The latest version of the flight software was uploaded and KidSat was declared operational. Within about two hours of initial setup and activation, the pilot school students were able to access and download their photographs of the Earth. KidSat operated until just before the docking with Mir and was set up again after docking until just before landing. After the Shuttle's Ku-band communication antenna was stowed, all remaining images were received post-landing.

Between 300 and 700 photos of the Earth were taken by the KidSat flight equipment at the request of the middle school students for each flight (see Figure 12, Table 2). The Mission Operations Team fully supported the mission with students in control. The Data System Team released the images to the students and the world at unprecedented speeds and created a digital animation "flyby" using an STS-76 image of Saudi Arabia and topographic data. Among the images were several excellent examples of sun glint on the ocean, coastlines, islands, deserts, mountain ranges, metropolitan areas, rivers, and clouds – lots of clouds. The Exploration Team and the students in the middle schools focused their explorations during the mission on Kangaroo Island, the Rift Valley in Africa and the Aral Sea for the first flight, Venice and the Gaza Strip for the second flight and the fires in Indonesia and Manaus for the third flight.

Education Highlights

Academic content, leadership development, community outreach, and technology integration are areas KidSat showed exemplars for an educational program. Primary research opportunities abounded for all students. Some students were inspired by science teleconferences where students interacted with scientists discussing El Nino's effect on the forests of Indonesia and the Amazon, for example. Science symposiums provided the spark for other students. In one school, students crawled on a gymnasium floor covered with large Operational Navigation Charts as they worked in teams to identify features in their KidSat images. Another group wrote poetry in partnership with renowned poets (see Green 1999), while others discussed migratory bird flightways, plate tectonics, and Amazon deforestation with university and NASA scientists.

Both science teleconferences and science symposiums modeled the working partnership scientists employ in their real life studies. Students were part of these partnership and experienced the workings of science as well as gaining valuable information about their own topics of interest.

Leadership came at many levels for KidSat students. Training astronauts to use the flight software and set up the KidSat camera, news conferences with local television stations, leading a Congressman on a tour of a SMOC, speaking to service organizations and at international conferences all became part of the KidSat program. Student published papers that shared the successes of KidSat with others. In each occasion students presented the project and their results with a poise and knowledge expected of true leaders.

KidSat provided academic content through the integration of technology in multiple curriculum areas. Science, mathematics, geography, history and English were dramatically enhanced with the use of KidSat data. As students searched Internet data bases for relevant data, asked scientists questions, and submitted image requests, educators saw the relevance and importance of technology as a tool within their curriculum and an enabler of quality education. The excitement in SMOCs across the country as they received their first images was exhilarating. Technology no longer was an add-on in the classroom but integral to success. The thought of geographic isolation was dissolved as KidSat students used technology to participate in a global team.

Exploration Challenges

Student investigations are one of the primary components of the KidSat project. Students collect and analyze data with the assistance of scientists, engineers and teachers. The results of their analyses are published on the KidSat web page or in journals. Successful examples are by Fisher and Fisher (1999), Tseng et al. (1999) and Barr et al. (1999). With the excellent quality of these investigations, scientists, engineers, and educators discussed the ratio of completed investigations to the total number of students involved with KidSat and found that that the number of completed (on line) investigations was small compared to the total number of students. The question of why such an exciting and engaging project had so few finished products was raised? Reasons included the social demands of today's teenagers, technological, and time constraints in middle schools.

Many of the students involved with KidSat were leaders in other areas of school life: student body officers, athletes, artists, musicians, and club members. Activities outside of school also forced students to constantly balance their social and academic lives. Many schools focused their energies on the Shuttle launch and image acquisition. This major commitment of time and energy on the part of students and staff provided immediate results to the KidSat members, whereas gratification from investigations was not episodic and required long term commitment with unknown results.

KidSat highlighted the necessity for in depth reflection in science; yet in middle schools there is often not the time available for long term investigation and revision. KidSat was the catalyst for providing opportunities to integrate curriculum, but at the same time was caught in this time dilemma. Students and teachers strove to devote the time necessary for completion of investigations, but were committed to address state and district curriculum requirements.

Technological drawbacks ranged from hardware restraints within schools to lack of training for teachers and students in the creation of on line products. Software and hardware compatabilities, integrated pathways, restricted Internet access, and ongoing development of technology resources impeded the publication of on line products.

Despite the lack of on line products, KidSat students completed investigations that were published as multi-media presentations and articles in educational and scientific journals. Additionally students shared their findings at science and mathematics conferences, college classes and community groups .

Summary and Conclusions

Students had a clear understanding of the goals of the mission, and their function in achieving said goals. They applied concepts and skills in the operation of the SMOCs, made decisions and were able to carry out the mission with guided adult supervision, worked in teams and used cooperative learning methods and skills, developed proficiency in using a wide range of technology, and were excited to be part of something that was real and ongoing. Students had a strong sense of ownership and pride, learned to adapt and adjust to changes during the mission, were highly engaged during the project, grew in their sense of personal responsibility, and improved their communication skills. Students were in charge (communicating with the Gateway, plotting the orbital tracks based on the descending node, selecting targets, confirming the METs, cross checking with the weather, entering the selections into the Data System, and retrieving their images). Students applied knowledge gained to new explorations and investigations, and were able to express an experienced understanding of the KidSat Project. Student learning went from a limited to an expanded view of the Earth. Students now have a whole new way of seeing the world.

Acknowledgments
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Figures

Figure 1	Overall KidSat design.
Figure 2	KidSat overall infrastructure including links from the pilot classrooms to UCSD to JSC to the Shuttle via DomSat, White Sands and TDRS for commanding; and from the Shuttle to JSC via TDRS/White Sands/DomSat to JPL via the Science Internet to the pilot classrooms for data.
Figure 3	KidSat cameras, Thinkpad, and links to the Shuttle.
Figure 4	La Canada High School students test the procedures for installing the KidSat cameras using the Shuttle Simulator's overhead window at JSC.
Figure 5	Data System Image Viewer web page showing the image as displayed to the students. Images are downloaded from this page of the Data System web interface. Images may be downloaded at a variety of resolutions and formats depending on the Internet capabilities of the schools.
Figure 6	Stereo pairs from STS-76 shown in a format that may be viewed using a stereopticon. Top: Mediterranean (01/01:51:23 - left, 01/01:51:13 - right); middle: Thunderstorm over Sudan (01/02:01:39 - left, 01/02:01:24 - right); Bottom: Spain (01/01:51:12 - left, 01/01:50:06 - right).
Figure 7	Outline for the three curriculum modules created for the KidSat pilot program.
Figure 8	The Aral Sea as viewed during STS-76 at MET 00/21:18:35. This black and white version of the original color image was acquired with a 50 mm lens on March 23, 1996 by Washington Accelerated Learning Center. The center latitude and longitude are 44.44N and 59.42E, respectively and the frame size is 102 x 153 km. North is toward the lower right corner of the image.
Figure 9	The Rio Xingu site selected by Buist. The Rio Xingu is a South American tributary to the great Amazon River in Brazil. The image was acquired at MET 01/08:08:12 with a 50 mm lens on March 23, 1996 by Buist Academy. The center latitude and longitude are 3.61S and 52.30W, respectively and the frame size is 142 x 213 km. North is toward the upper right corner of the image. There are scattered clouds over the river and the river's course can be distinctly seen as a muddy-colored waterway winding through the rain forest.
Figure 10	The image of the Rio Xingu shown as Figure 9 was compared with a set of ONC maps detailing the area. The two pathways of the river, one from the KidSat image and the other from the map which was nine years older than the KidSat image, were overlaid to show how the river's course has changed over time.
Figure 11	Locations of images acquired on all three KidSat missions.

Table 1

STS-76	
Samuel Gompers Secondary School	San Diego, CA
Washington Accelerated Learning Center	Pasadena, CA
Buist Academy	Charleston, SC
STS-81	
Bennett Middle School	Salisbury, MD
Washington Accelerated Learning Center	Pasadena, CA
Ronald McNair Magnet School	Cocoa, FL
Canton Middle School	Baltimore, MD
Costano Middle School	East Palo Alto, CA
Crittendon Middle School	Newport News, VA
York County Middle School	Yorktown, VA
CollinWood Middle School	Cleveland, OH
Webster Magnet School	Webster, TX
Lewis Middle School	San Diego, CA
Olive Pierce Middle School	Ramona, CA
Central	Omaha, NE
Gompers Secondary School	San Diego, CA
Buist Academy	Charleston, SC
Laing	Pleasant, SC
Canford School	Dorset, England
Kearsney College	Kwa Zulu Natal, SA*
STS-86	
Fortuna Elementary School	Fortuna, CA
Cutten Middle School	Arcata, CA
Jacoby Creek Middle School	Arcata, CA
Pacific Union School	Arcata, CA
Valley Junior High School	Carlsbad, CA
Costano Middle School	East Palo Alto, CA
La Cañada High School	La Cañada, CA
Olive Pierce Middle School	Ramona, CA
Bell Junior High School	San Diego, CA
Challenger Middle School	San Diego, CA
Gompers Secondary School	San Diego, CA
Lewis Middle School	San Diego, CA
West Middle School	Colorado Springs, CO
Ronald McNair Magnet School	Cocoa, FL
Space Coast Middle School	Cocoa, FL
California Trail Junior High School	Olathe, KS
Foley Middle School	Berea, KY
Carroll County Middle School	Carrollton, KY
Canton Middle School	Baltimore, MD
Bennett Middle School	Salisbury, MD
Stone Middle School	Wiggins, MS
Dana College	Blair, NE
Arbor Park Middle School	Blair, NE
Fort Calhoun Middle School	Blair, NE
Millard Central Middle School	Omaha, NE
University of Nebraska, Omaha	Omaha, NE
Shiprock Intermediate School	Kirtland, NM
Davis Drive Middle School	Apex, NC
Pine Hall Elementary School	Pine Hall NC
Martin Middle School	Raleigh, NC
Collinwood Middle School	Cleveland, OH
Putnam City Schools	Oklahoma City, OK
Central Middle School	Oklahoma City, OK
Cooper Middle School	Oklahoma City, OK
Hefner Middle School	Oklahoma City, OK
Mayfield Middle School	Oklahoma City, OK
Western Oaks Middle School	Oklahoma City, OK
Buist Academy	Charleston, SC
Drayton Hall Middle School	Charleston, SC
James Island Middle School	James Island, SC
Laing Middle School	Mount Pleasant, SC
Patrick Henry Middle School	Sioux Falls, SD
Grishman Middle School	Austin, TX
Seabrook Intermediate School	Seabrook, TX
Webster Magnet School	Webster, TX
Crittendon Middle School	Yorktown, VA
Outlook Elementary School	Outlook, WA
Warwood Middle School	Wheeling, WV
Canford School	Dorset, England
Kearsney College	Kwa Zulu Natal, SA*
Highway 1	Washington, D.C.

** South Africa

Table 2: Summary of Missions

Mission	Launch Date	Landing Date	Duration (days)	No. Orbs	Crew	Hours of Ops	No. Schools	No. Students	No. Photos	Mission Goals
STS-76	Mar. 22, 1996	Mar. 31, 1996	9.22	144	Kevin Chilton, Richard Searfoss Ronald Sega Richard Clifford Linda Godwin* Shannon Lucid	37	3	~380	326	3rd Mir docking Crew delivered (Lucid)
STS-81	Jan. 12, 1997	Jan. 22, 1997	10.21	160	Mike Baker Brent Jett Jeff Wisoff John Grunsfeld Marsha Ivins* Jerry Linenger John Blaha	72	17	~3000	540	5th Mir docking Crew exchange (Linenger/Blaha)
STS-86	Sept. 25, 1997	Oct. 6, 1997	10.80	169	James Wetherbee Mike Bloomfield* Scott Parazynski Vladimir Titov Jean-Loup Chretien Wendy Lawrence David Wolf Michael Foale	38	52	~6000	656	7th Mir docking Crew exchange (Foale/Wolf)

*KidSat Payload Officer

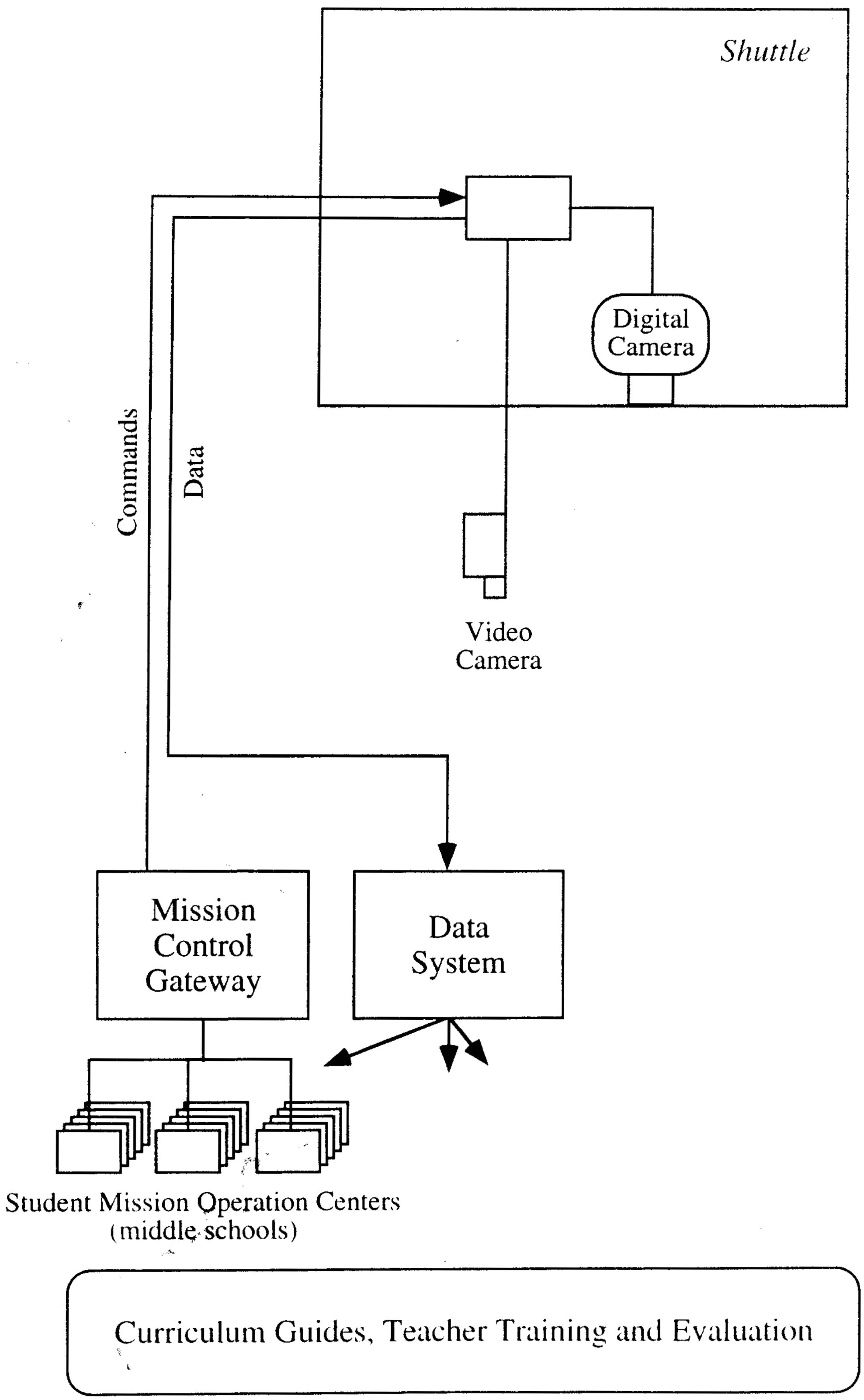

Shuttle
Digital Camera
Commands
Data
Video Camera
Mission Control Gateway
Data System
Student Mission Operation Centers (middle schools)
Curriculum Guides, Teacher Training and Evaluation

Fig. 1

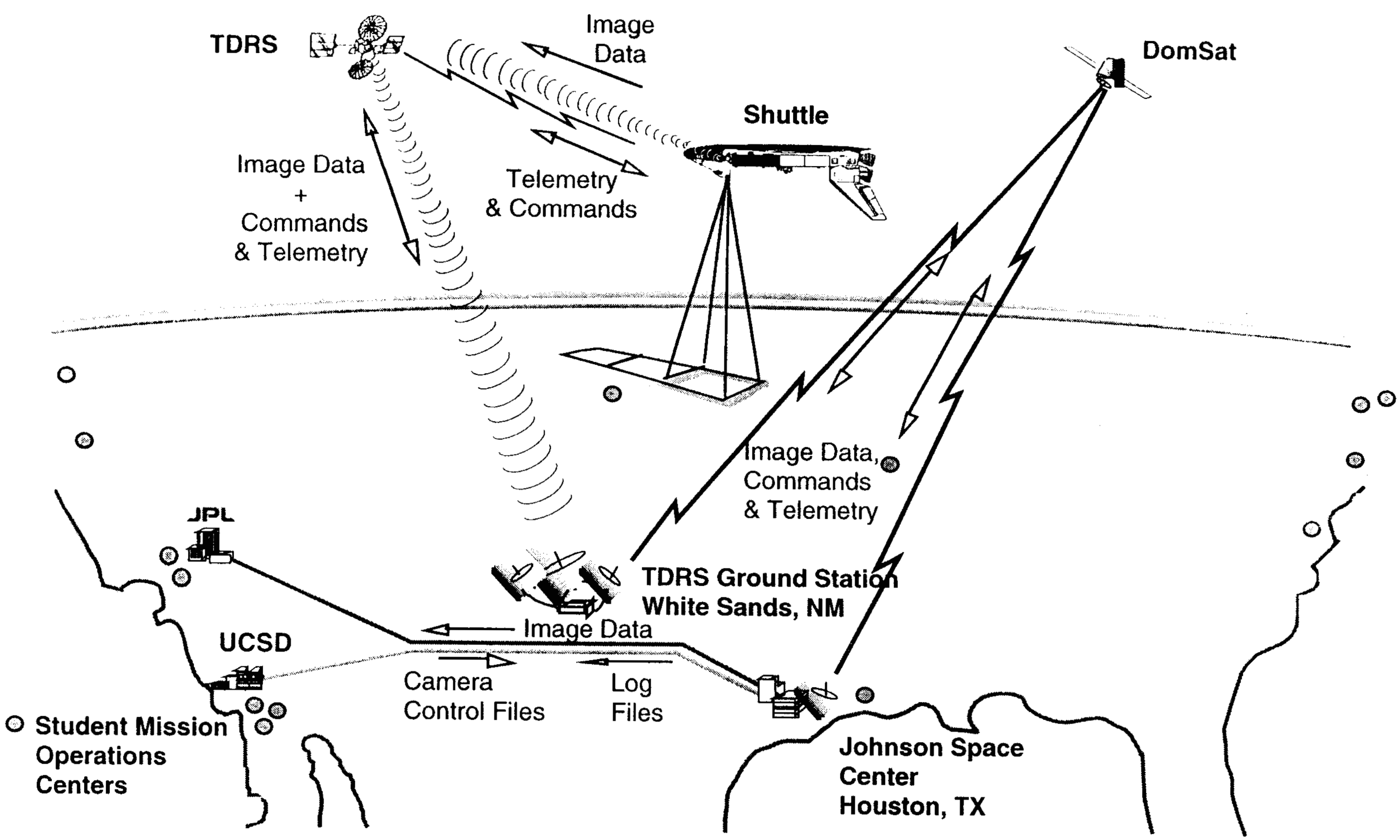

TDRS
Image Data
DomSat
Shuttle
Image Data
+
Commands
& Telemetry
Telemetry
& Commands
Image Data,
Commands
& Telemetry
JPL
TDRS Ground Station
White Sands, NM
UCSD
Image Data
Camera
Control Files
Log
Files
Student Mission
Operations
Centers
Johnson Space
Center
Houston, TX

Fig. 2

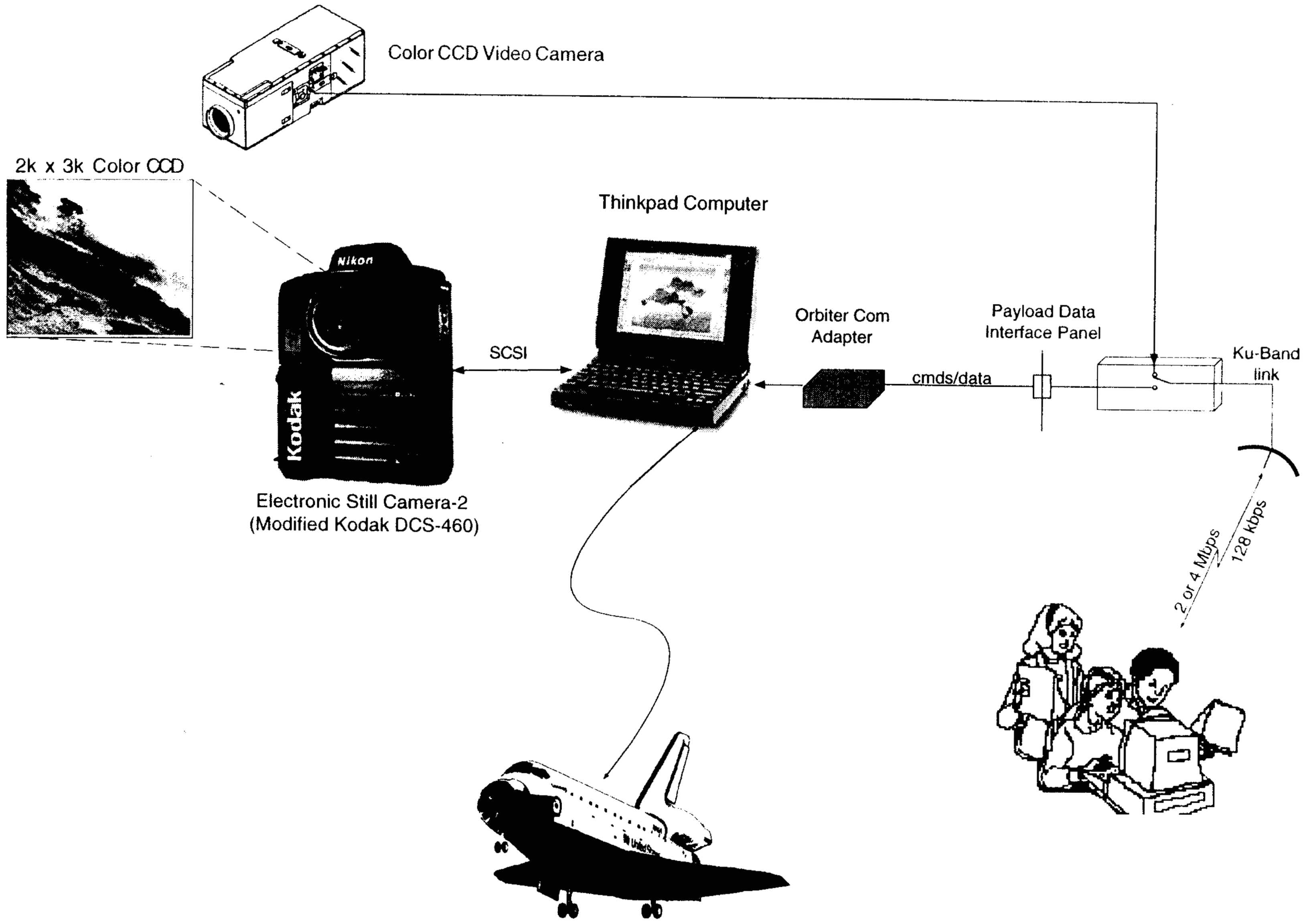

Color CCD Video Camera
2k x 3k Color CCD
Nikon
Kodak
Thinkpad Computer
SCSI
Orbiter Com
Adapter
cmds/data
Payload Data
Interface Panel
Ku-Band
link
Electronic Still Camera-2
(Modified Kodak DCS-460)
2 or 4 Mbps
128 kbps

Fig. 3

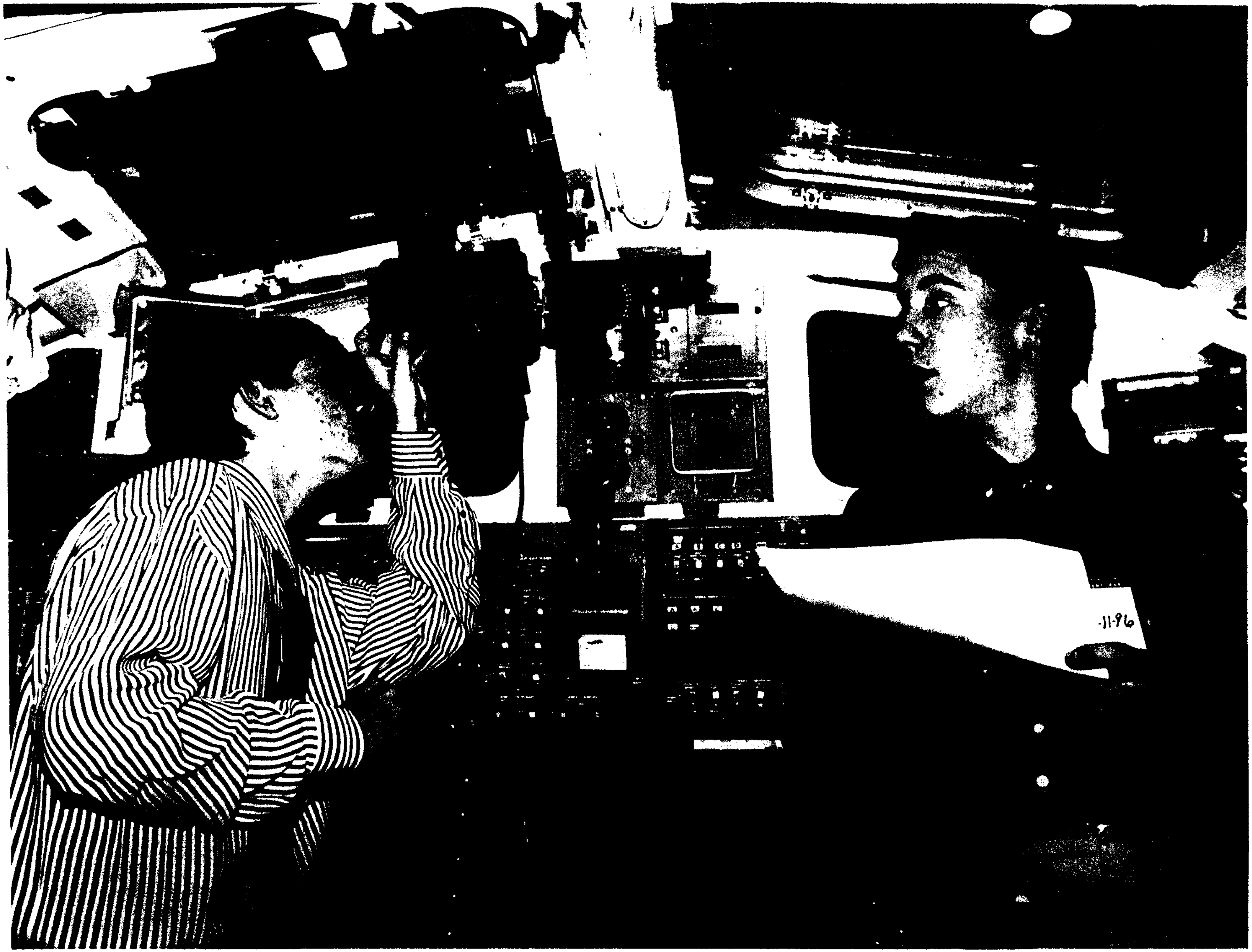
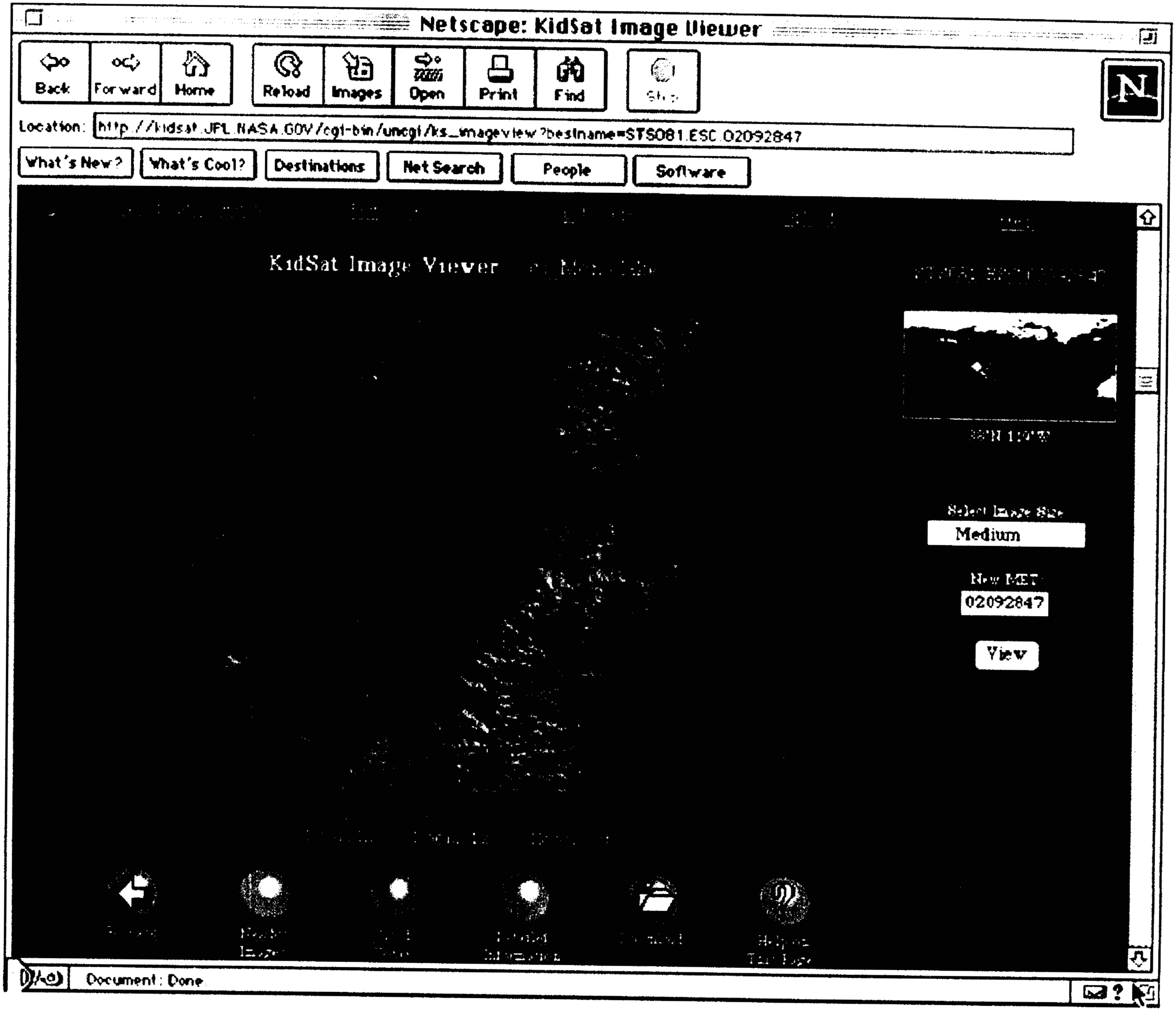


Fig. 4



Netscape: KidSat Image Viewer
Back
Forward
Home
Reload
Images
Open
Print
Find
Location: http://kidsat.JPL.NASA.GOV/cgi-bin/uncgi/ks_imageview?bestname=STS081.ESC.02092847
What's New?
What's Cool?
Destinations
Net Search
People
Software
KidSat Image Viewer
Medium
02092847
View
Document: Done

Fig. 5

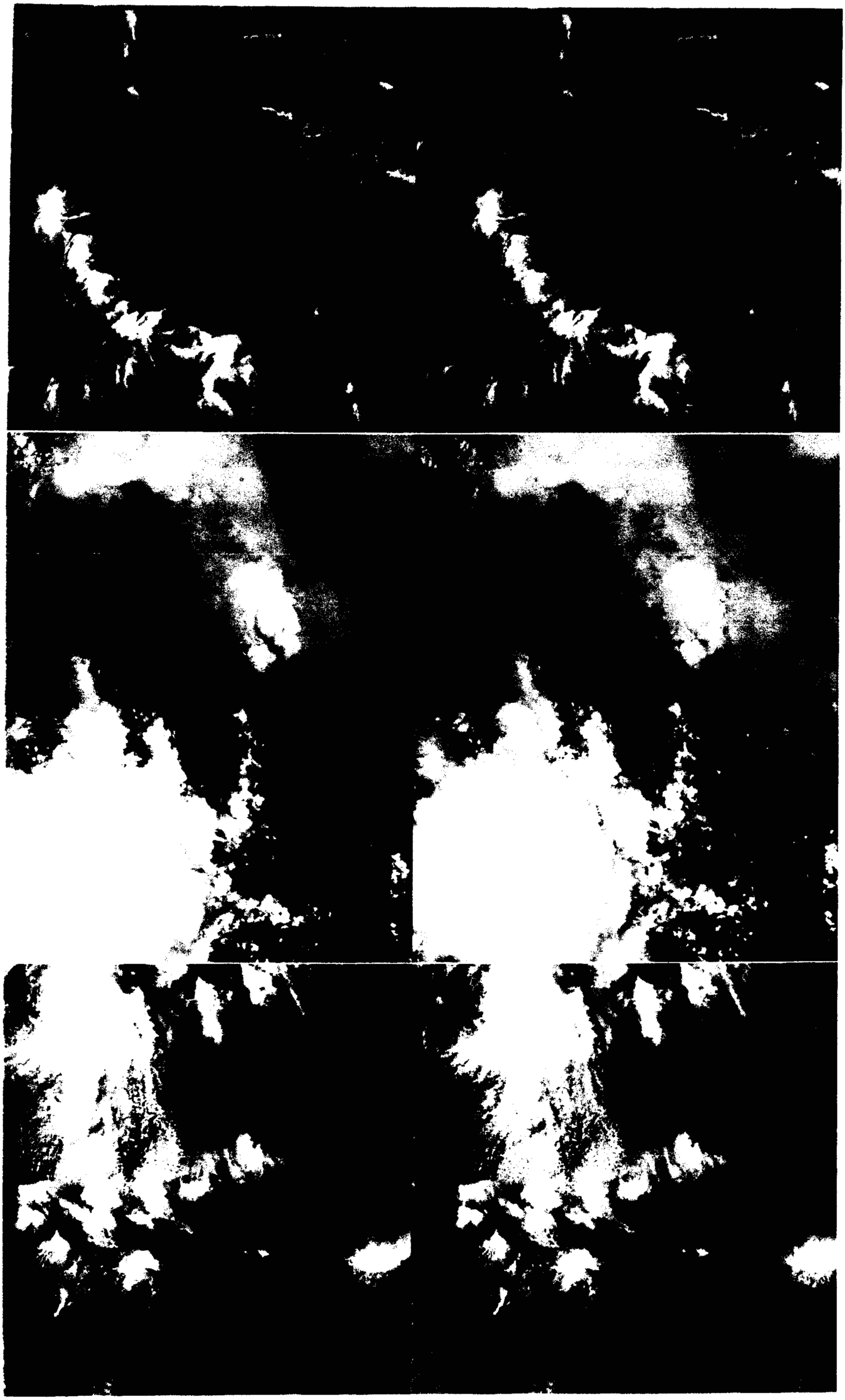


Fig. 6

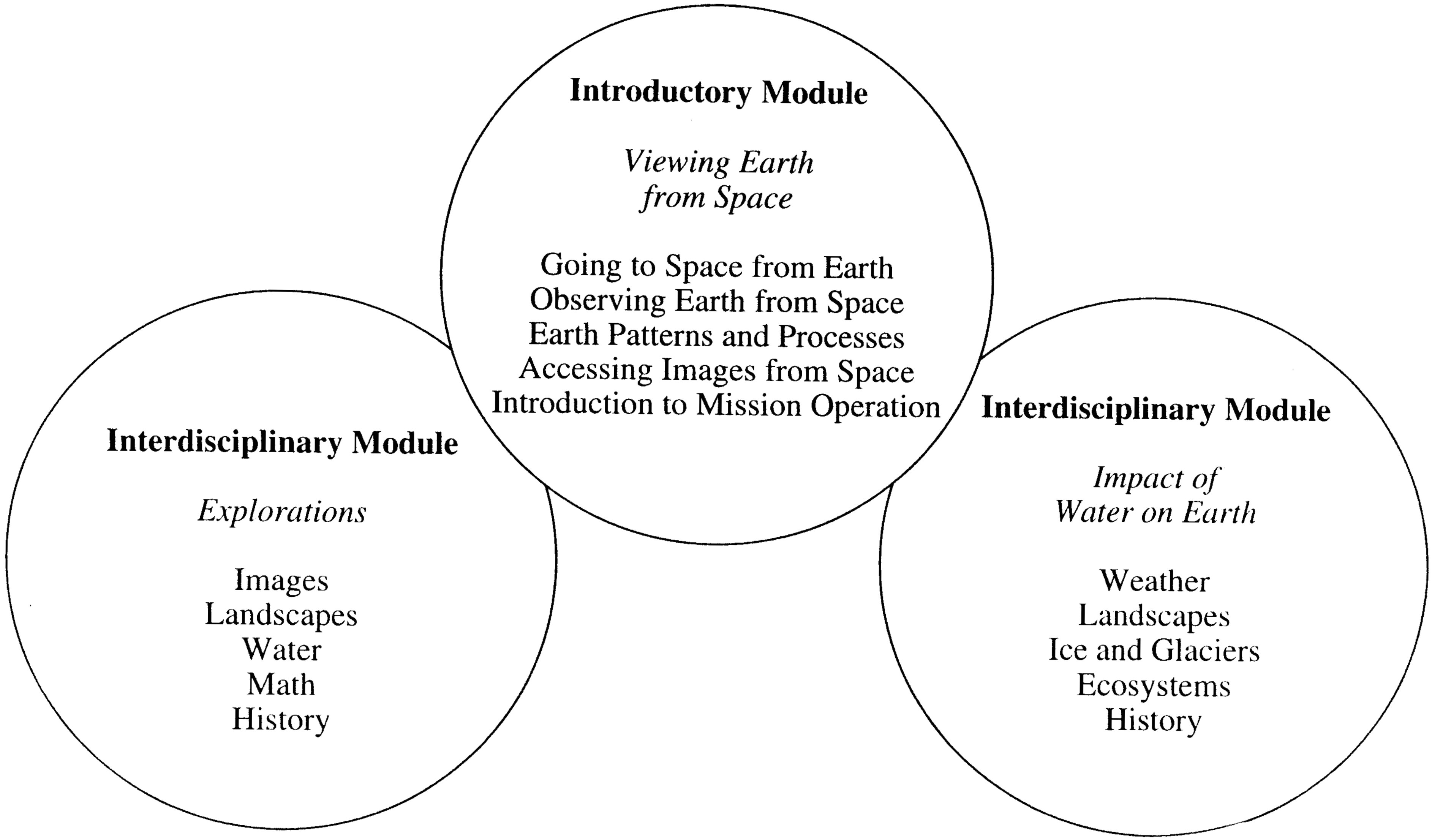

Introductory Module
Viewing Earth from Space
Going to Space from Earth
Observing Earth from Space
Earth Patterns and Processes
Accessing Images from Space
Introduction to Mission Operation
Interdisciplinary Module
Explorations
Images
Landscapes
Water
Math
History
Interdisciplinary Module
Impact of Water on Earth
Weather
Landscapes
Ice and Glaciers
Ecosystems
History

Fig. 7

Fig. 8

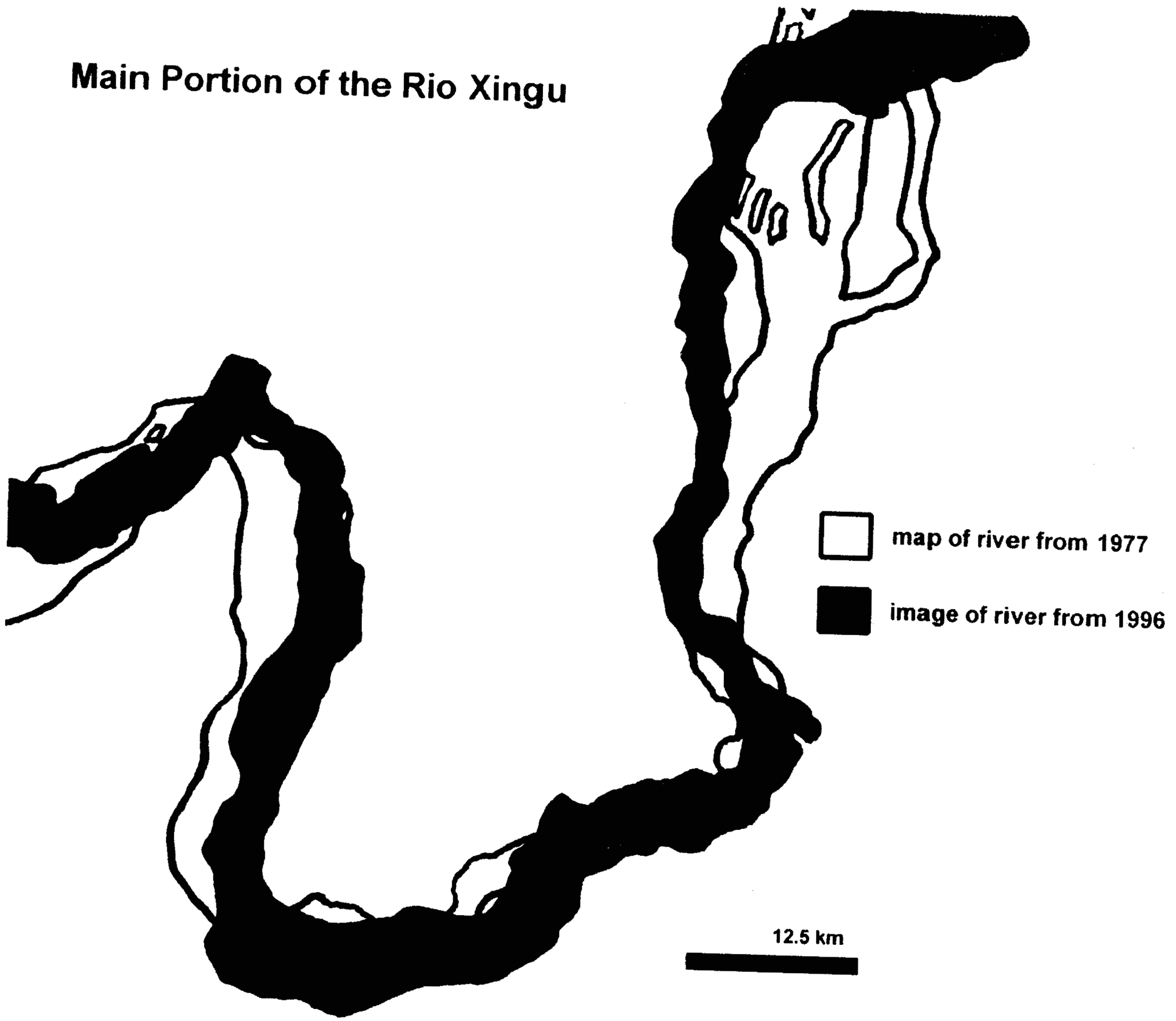

Main Portion of the Rio Xingu
map of river from 1977
image of river from 1996
12.5 km

Fig. 10

Fig. 12